

Axial Capacity of Piles in Intermediate Geomaterials (IGM)

MDT Project No. 8117-32

Meeting Minutes for 3rd Quarter 2007 Progress Tele-Conference

Meeting Date: October 29, 2007

Time: 01:30 – 3:00 pm

Participants: MDT: Brian Collins, Cameron Kloberdanz, Sue Sillick

MSU: Heather Brooks, Eli Cuelho, Bob Mokwa

Meeting Minutes by Bob Mokwa

An overview was provided by MSU of the primary work tasks to date. As summarized below, the major tasks included: 1) literature review, 2) collection and organization of MDT project files, 3) analyses and 4) miscellaneous action items.

1) Literature Review

The literature review has been expanded to further examine the relationship between static pile loading tests and field dynamic tests (CAPWAP). Bob reported on discussions he has had with two of the originators of GRLWEAP and CAPWAP. They indicated, in general, that static analysis methods are not very accurate, and that MDT's pile capacity predictions may be typical of what could be expected when using static methods such as the DRIVEN program to predict capacities of piles driven into IGMs. Additional literature research will be conducted to compile a data base that we will use to compare static load test results with field dynamic tests and static analytical methods. This will provide a benchmark to establish or quantify a typical error level that could be expected for these types of predictions. Table 5 provides a snapshot of a portion of the referenced literature that has been compiled to date. An emphasis will be placed on piles driven into IGMs.

2) Collection and Organization of MDT Project Files

Tables 1, 2, and 3 summarize the status of MDT project data that has been collected. Comments made during the meeting regarding these tables, include the following.

i) The Poplar River project will henceforth be named the West Fork Poplar River project.

ii) The Swan River project will be removed from the list of priority projects because of questionable CAPWAP results.

iii) The MSU team greatly appreciates the gallant efforts of Brian, Amanda, and Cameron in assembling all the project data. At this time, it appears we have complete files of all the priority projects for our analyses. MSU will directly contact Brian or Cameron if any additional questions or needs arise regarding project information.

3) Analyses

Table 4 and the attached draft figures labeled A.1, A.2, and B.1 thru B.6 were discussed.

i) Table 4 shows compressive stresses in the piles during installation (dynamic stresses) as a percentage of the pile yield strength. Yield strengths were obtained from CAPWAP records for each project.

ii) Draft Figures A.1 and A.2 reflect updates from the last meeting, which include removing data points for gravel IGMs and indicating the project of origin.

iii) Draft Figures B.1 thru B.6 directly compare the designers' input strength values (ϕ' or c_a) with corresponding values that would be necessary to achieve a direct match with CAPWAP results for shaft, toe, and shaft + toe resistances.

iv) Comments made during the meeting included making sure the magnitudes of the scales are consistent between plots, using different symbols to help distinguish between gravel and formation materials, and practical reasons for the designers to limit the value of ϕ' that is input into the DRIVEN program.

4) Miscellaneous Action Items

i) MSU will further examine the methods that GRLWEAP uses to estimate pile capacity. GRLWEAP capacity estimates will be compared with results from DRIVEN.

ii) Bob will contact Tri Buu from the Idaho Department of Transportation to query him regarding potential research that Idaho has conducted that may be relevant to this study.

iii) MSU will examine Colorado DOT's methods for conducting static analyses of piles driven into IGMs. As appropriate, MSU will compare these methods with DRIVEN and GRLWEAP results using data from the priority projects.

iv) A written progress report will be submitted for the next quarter (4th Quarter-2007), in January 2008. A conference call will be scheduled a few weeks after the report is submitted to discuss any comments.

The following table provides an update on the budget through the 3rd Quarter (September 30) 2007.

TABLE 1. Budget Summary through September 30, 2007

Budget Category	Budgeted Funds	Spent Quarter 3-07	Total Spent	Total Remaining
Salaries	\$15,039.00	\$0.00	\$10,836.44	\$4,202.56
Benefits	\$4,525.00	\$0.00	\$2,350.85	\$2,174.15
In-State Travel	\$300.00	\$0.00	\$400.07	(\$100.07)
Out-of-State Travel	\$0.00	\$0.00	\$0.00	\$0.00
Expendable Supplies	\$50.00	\$0.00	\$0.00	\$50.00
Tuition	\$0.00	\$0.00	\$0.00	\$0.00
Subcontracts	\$0.00	\$0.00	\$0.00	\$0.00
MDT Direct Costs	\$19,914.00	\$0.00	\$13,587.36	\$6,326.64
Overhead	\$3,983.00	\$0.00	\$2,717.50	\$1,265.50
MDT Share	\$23,897.00	\$0.00	\$16,304.86	\$7,592.14
WTI/MSU Share	\$16,144.00	\$4,038.77	\$16,144.00	\$0.00
Total	\$40,041.00	\$4,038.77	\$32,448.86	\$7,592.14

List of Abbreviations and Symbols

Definitions

Running	Actual driven pile length exceeds the anticipated design length
Early Refusal	Pile is driven to a very low blow count at a depth that is less than the anticipated design length.

Pile Abbreviations

P	Pile perimeter
DS	Drilled shaft
OP	Open-ended pipe pile
CP	Close-ended pipe pile
RC	Reinforced concrete pile
PSC	Prestressed concrete pile
H	H-pile

Soil Type or IGM

IGM	Intermediate Geomaterial
S	Sandstone
Si	Siltstone
C	Claystone
Sh	Shale
G	Dense Gravel (SPT refusal)

Definitions from Tables and Figures

$Q_{CW \text{ shaft}}$	CAPWAP shaft capacity
N_{s2}	$= Q_{CW \text{ shaft}}/P$ = CAPWAP shaft resistance normalized by pile perimeter (P)
c_a	= adhesion = αc_u ; where, α is the Tomlinson adhesion factor and c_u is the undrained shear strength
P	Pile perimeter
f_y	Pile yield strength
Allow. Drive	Allowable driving stress
Max	Maximum driving stress within the pile
Com. Bot.	Compressive stress at the bottom of the pile
Dav.	Davison Method of Static Load Test Analysis

Table 1. Summary of Projects and Data Categories

Project	CN #	IGM Type	PDA on Project	Bore Logs	Design Report	Driving Logs	PDA Report	DRIVEN Calcs.	GRLWEAP Calcs.	Plans	Hammer Data
*Nashua – E & W	2144	Claystone, Shale	Y	Y	Y	Y	Y	Y	Y		Y
*N. Fork Poplar River	3417	Claystone, Sandstone, Siltstone	Y	Y	Y	Y	Y	Y	Y		Y
*Bridger Cr. – NE of Bozeman	4230	Dense Silty Gravel	Y	Y	Y	Y	Y	Y	Y		Y
*Big Muddy Cr. – SE of Redstone	4239	Claystone	Y	Y	Y	Y	Y	Y	Y		Y
*Keyser Cr. – W of Columbus	4244	Shale, Sandstone	Y	Y	Y	Y	Y	Y	Y	Y	Y
*Medicine Tree	Q744	Dense Silty Gravel	Y	Y	Y	Y	Y	Y	Y	Y	Y
*Vic. White Coyote Rd.	1744	Dense Silty Gravel	Y	Y	Y	Y	Y	Y	Y	Y	Y
*Goat Creek	4226	Dense Silty Gravel	Y	Y	Y	Y	Y	N/A	Y	Y	Y
*Swan River – SE of Ferndale	4228	Dense Silty Gravel	Y	Y	Y	Y	Y	Y	Y	Y	Y
NW Sidney – N	1041	Siltstone, Coal	N	Y	Y	Y		Y		Y	Y
Milk River – Zurich	1154	Sandstone, Siltstone	N	Y	Y						
Volberg – N & S	1514	Claystone, Siltstone, Sandstone, Coal	N	Y	Y			Y		Y	
Colstrip – S	2148	?	N			Y					Y
Angela – N & S	2461	Shale	N	Y	Y	Y		Y	Y		Y
Poplar River – NW	2792	Claystone	N	Y	Y	Y		Y			Y
Willow Cr. – NE of Blackfoot	3399	Shale	N	Y				Y		Y	
Cutbank Cr. – NE of Blackfoot	3400	Shale	N	Y	Y						
Shokin Cr. – S of Ft. Benton	3887	Shale, OC Clay	N	Y	Y			Y	Y	Y	Y
Little Missouri Rv. – E of Capitol	3988	Shale, Sandstone	N	Y	Y					Y	
Tongue River – Miles City	3989	Dense Silty Gravel, Siltstone, Sandstone	N	Y				Y	Y		Y
Tongue River – Miles City	4174	Dense Silty Gravel, Siltstone, Sandstone	N	Y				Y	Y		Y
Structures – S of Pray	4232	Dense Silty Gravel	N	Y				Y	Y	Y	Y
USRS Canal – NE of Augusta	4235	Claystone, Siltstone, Sandstone	N	Y	Y	Y					Y
Wolf Cr. – E of Vida	4268	Shale, Coal, Siltstone	N	Y	Y			Y		Y	
Big Hole Rv. – SW of Jackson	4539	Sandy Gravel	N	Y	Y	Y			Y	Y	Y
Milk River – W of Chinook	5559	OC Clay, Sandstone, Siltstone, Shale	N	Y	Y			Y	Y		Y

Notes for table:

- 1) “*” Indicates 1st priority projects for analysis (see Table 2).
- 2) Bolded Projects have enough information to complete full analysis.
- 3) Y = yes, WTI has information; N = no, WTI does not have PDA information

Table 2. Summary of Analytical Tasks for 1st Priority Projects

Project	CN #	Data Input	Soil Profile Drawing	DRIVEN Analysis	GRLWEAP Analysis	Notes
Medicine Tree	Q744	X				
Vic. White Coyote Rd.	1744	X				
Nashua-E &W	2144	X	X	X	X	
N. Fk Poplar	3417	X	X	X	X	
Goat Creek	4226	X				
Swan River	4228	X	X			Should this be included in the analysis?
Bridger Cr.	4230	X	X	X	X	
Big Muddy Cr.	4239	X	X	X	X	
Keyser Cr.	4244	X	X	X	X	

Notes:

- 1) "X" indicates completed task.

Table 3. Project Construction Summaries (a)

Project CN	IGM Type	Pile Location	Bent Station	Pile Type/Size	Total Embedded Length (m)	Pile Length in IGM (m)	q _u (kN)	SPT N-Value* (N ₁) ₆₀
Q744	Silty Gravel	Bent 1 Bent 2	528+44.015 528+83.985	508mm OP 508mm OP	30.17 30.11			
1744	Silty Gravel							
2144	Shale Claystone	Bent 1 Bent 3 Overflow 1	236+01.00 236+47.90 249+74.25	508mm CP 508mm OP 508mm OP	27.48 27.58 25.77	5.19 1.68 4.77	206 Sh 83 Sh 223 Sh	N/A N/A N/A
3417	Claystone Sandstone	Bent 1 Bent 2 Bent 3 Bent 4 Overflow 1 Overflow 2 Overflow 3	5+51.02 5+82.26 6+13.75 6+44.98 7+42.26 7+71.50 8+00.74	406mm CP 762mm OP 762mm OP 406mm OP 406mm OP 610mm OP 406mm OP	12.79 14.36 14.62 12.80 15.22 13.62 16.2	9.74 8.46 8.52 5.79 8.52 9.92 12.20	294 C; 40,479 S 197 C; 367 S 449 C; 545 S 579 C; 523 S 263 C; 2,808 S 328 S; 458 C; 868 C,S,Si 709 C; 19,390 S	N/A N/A N/A N/A N/A N/A N/A
4226	Silty Gravel	Bent 1 Bent 2	944+45.4 944+66.386	406mm CP 406mm CP	9.3 8.84			
4228	Silty Gravel	Bent 1 Bent 2N Bent 2S	10+02.578 10+25.914 10+25.914	610mm OP 610mm OP 610mm OP				
4230	Silty Gravel	Bent 3 Bent 4	35+20.32 35+28.82	610mm OP 406mm OP	8.58 7.23	4.58 3.23	N/A N/A	R* R*
4239	Claystone	Bent 1 Bent 2 Bent 4	11+20.50 11+34.25 11+61.99	H 310x125 406mm CP H 310x125	33.04 31.14 41.24	4.08 2.18 12.28	N/A N/A N/A	N/A N/A R*
4244	Shale/ Sandstone	Bent 1 Bent 2	18+06.26 18+35.74	H 310x125 H 310x125	9.24 9.21	1.925 1.895	9,549 Sh; 9,797 S N/A	N/A R*

1) q_u are an average for the IGM at the Bent (abbreviations are below).

S = Sandstone; Si = Siltstone; C = Claystone; Sh = Shale; SG = Silty Gravel

Interbedded layers have more than one IGM classification.

2) “*” indicates SPT refusal with greater than 50 blows/ 0.3m.

3) OP = open-ended pipe pile, CP = closed-ended pipe pile

4) **Table 3. Project Construction Summaries (b)**

Project CN	IGM Type	Pile Location	Pile Type and Size	Design Axial Capacity (kN)	Measured Axial Capacity (kN)	Design Pile Length (m)	Actual Pile Length (m)	Comments
Q744	Silty Gravel	Bent 1 Bent 2	508mm OP 508mm OP	2300 2300	1542, 2308* 956, 2140*,2152**	18 18	30.17 30.11	Running Running
1744	Silty Gravel	Bent 1			936, 1609*		21.02	
2144	Shale/Clay stone	Bent 1 Bent 3 Overflow 1	508mm CP 508mm OP 508mm OP	2720 2825 3150	2244 2388 3160*	29.3 28.9 26.2	27.48 27.58 25.77	Early Refusal Early Refusal Early Refusal
3417	Claystone/ Sandstone	Bent 1 Bent 2 Bent 3 Bent 4 Overflow 1 Overflow 2 Overflow 3	406mm CP 762mm OP 762mm OP 406mm OP 406mm OP 610mm OP 406mm OP	1810 3870 3870 1670 1790 2870 1560	1800 3845 3850 2074 2125 3074 2598	12.98 14.74 14.74 12.97 16.3 15.83 17.03	12.79 14.36 14.62 12.80 15.22 13.62 16.2	Early Refusal Early Refusal Early Refusal Early Refusal Early Refusal Early Refusal Early Refusal
4226	Silty Gravel	Bent 1 Bent 2	406mm CP 406mm CP					
4228	Silty Gravel	Bent 1 Bent 2N Bent 2S	610mm OP 610mm OP 610mm OP	4953 3721 3721	2324 2493* 2400, 2403*, 2332**			Running Running Running
4230	Silty Gravel	Bent 3 Bent 4	610mm OP 406mm OP	2600 2430	3200 3195	8.58 7.23	8.58 7.23	
4239	Claystone	Bent 1 Bent 2 Bent 4	H 310x125 406mm CP H 310x125	2025 2205 2025	2125 2370 2202	30.54 32.64 32.64	33.04 31.14 41.24	Running Early Refusal Running
4244	Shale/ Sandstone	Bent 1 Bent 2	H 310x125 H 310x125	2230 2230	3500 2550	12.22 12.22	9.24 9.21	Early Refusal Early Refusal

Notes

1) “*” indicates restrike capacity.

2) “**” indicates a second restrike capacity.

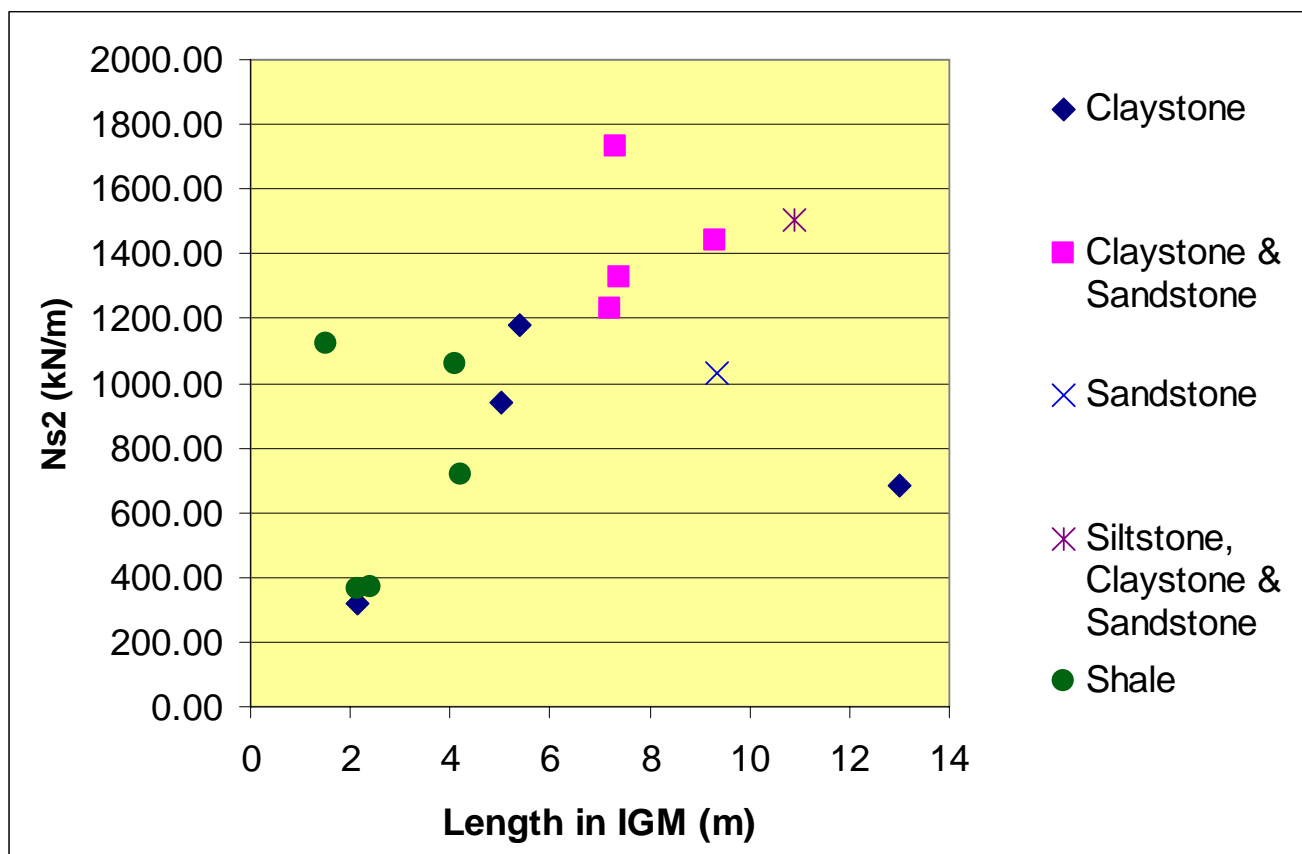


Figure A.1. Normalized Shaft Resistance Compared to Length in IGMs

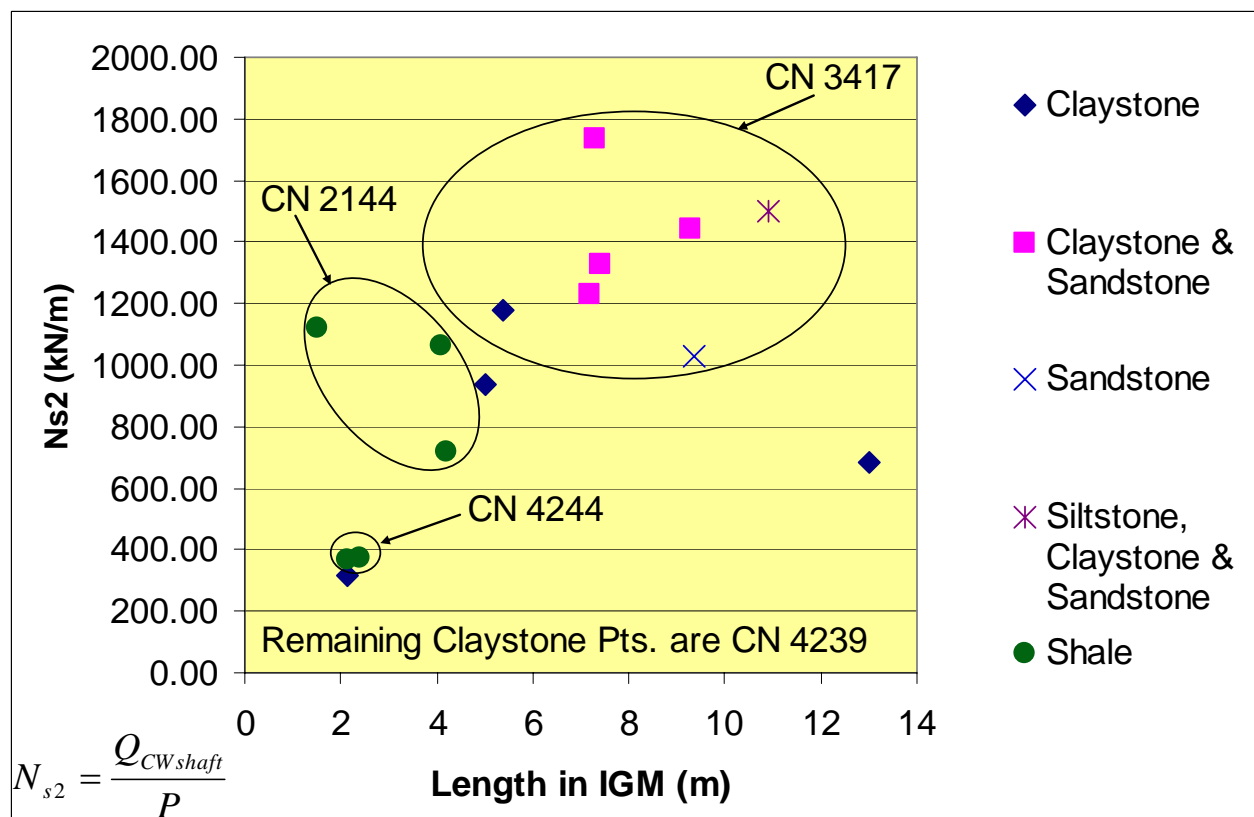


Figure A.2. Normalized Shaft Resistance Compared to Length in IGMs by Project

Table 4. Pile Driving Stresses within Piles

CN	Bent	Pile Size	Stresses				% of Allow. Driving Stress
			f _y (MPa)	Allow. Drive (MPa)	Max (MPa)	Com. Bot. (MPa)	
2144	1	508	310	279	221	133.5	79.21%
2144	3	508	310	279	220.6	107	79.07%
2144	O1	508	310	279	212.9	118	76.31%
2144	O1R	508	310	279	251.6	144.4	90.18%
3417	1	406	310	279	276.5	67.8	99.10%
3417	2	762	405	364.5	209.2	84.3	57.39%
3417	2R	762	405	364.5	230.4	56.6	63.21%
3417	3	762	405	364.5	194.4	96.9	53.33%
3417	4	406	310	279	261.8	30.6	93.84%
3417	O1	406	310	279	286.2	93	102.58%
3417	O2	610	310	279	180	45	64.52%
3417	O2R	610	310	279	240.9	58.4	86.34%
3417	O3	406	310	279	282.9	108.1	101.40%
4230	3	610	310	279	208.6	116.5	74.77%
4230	3R	610	310	279	233.3	19.1	83.62%
4230	4	406	310	279	248.1	152.5	88.92%
4239	1	310X125	241	216.9	194	85.5	89.44%
4239	2	406	241	216.9	219.9	123.4	101.38%
4239	4	310X125	241	216.9	190.5	132.5	87.83%
4244	1	310X125	345	310.5	209.9	255.2	67.60%
4244	2	310X125	345	310.5	214.8	245.6	69.18%

approximated from Graph

Average Maximum Stress: 227.98 Mpa

Standard Deviation: 59.82 MPa

Average % Error: 81.39%

Notes:

- 1) Driving stress equation is $0.9 \cdot f_y$ for both H and Pipe Piles (Tables 11-1 and 11-2).
- 2) Bolded cells have stresses within 90% of the allowable driving stresses.

Table 5. Dynamic and Static Capacity Correlation

Background Data		Static Values			Anal. Type	Dynamic Values			Reference
		Capacities (kN)				Capacities			
Soil Type	Pile Type	Shaft	Tip	Ult.		Shaft	Tip	Ult.	Author
Soil	Pipe 24x1/2"			1344				2292	Rausche, Robinson and Likins
Soil	PSC 24x24"			3204				3097	Rausche, Robinson and Likins
Soil	PSC 16x16"			997				378	Rausche, Robinson and Likins
Soil	PSC 16x16"			961				481	Rausche, Robinson and Likins
Soil	PSC 14x14"			997				627	Rausche, Robinson and Likins
Soil	PSC 16x16"			2648				3453	Rausche, Robinson and Likins
IGM - chalk	RC 275x275mm	890	910	1800		610	950	1560	Gravare and Hermansson
Soil	H 300mm			3605	Dav.			3200	Thompson
Soil	CP 300mm			2000	Dav.			1780	Thompson
Soil	PSC 300mm			2225	Dav.			2310	Thompson
Soil	H 300mm			1420	Dav.			1160	Thompson
Soil	CP 300mm			1335	Dav.			1600	Thompson
Soil	H 300mm			2800	Dav.			2890	Thompson
Soil	CP 300mm			2450	Dav.			2580	Thompson
Soil	Timber			670	Dav.			620	Thompson
Soil	PSC 300mm			1740	Dav.			1510	Thompson

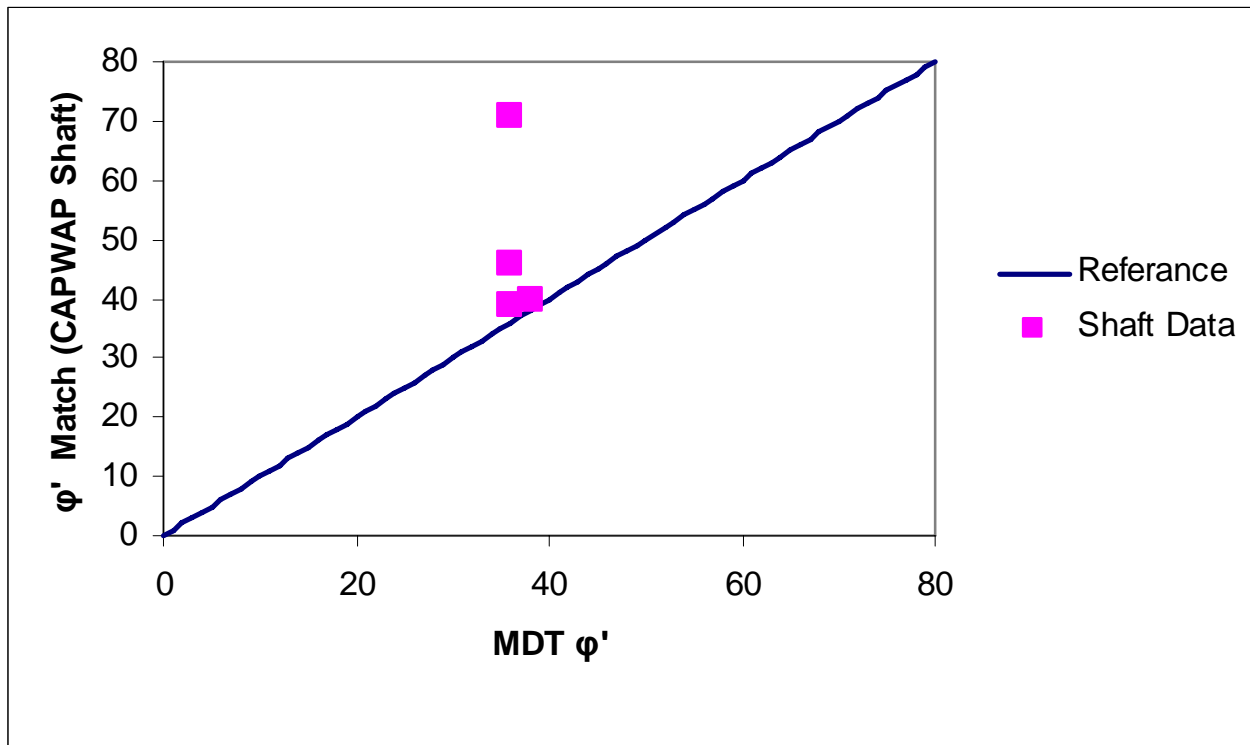


Figure B.1. Cohesionless Shaft Capacity Correlation

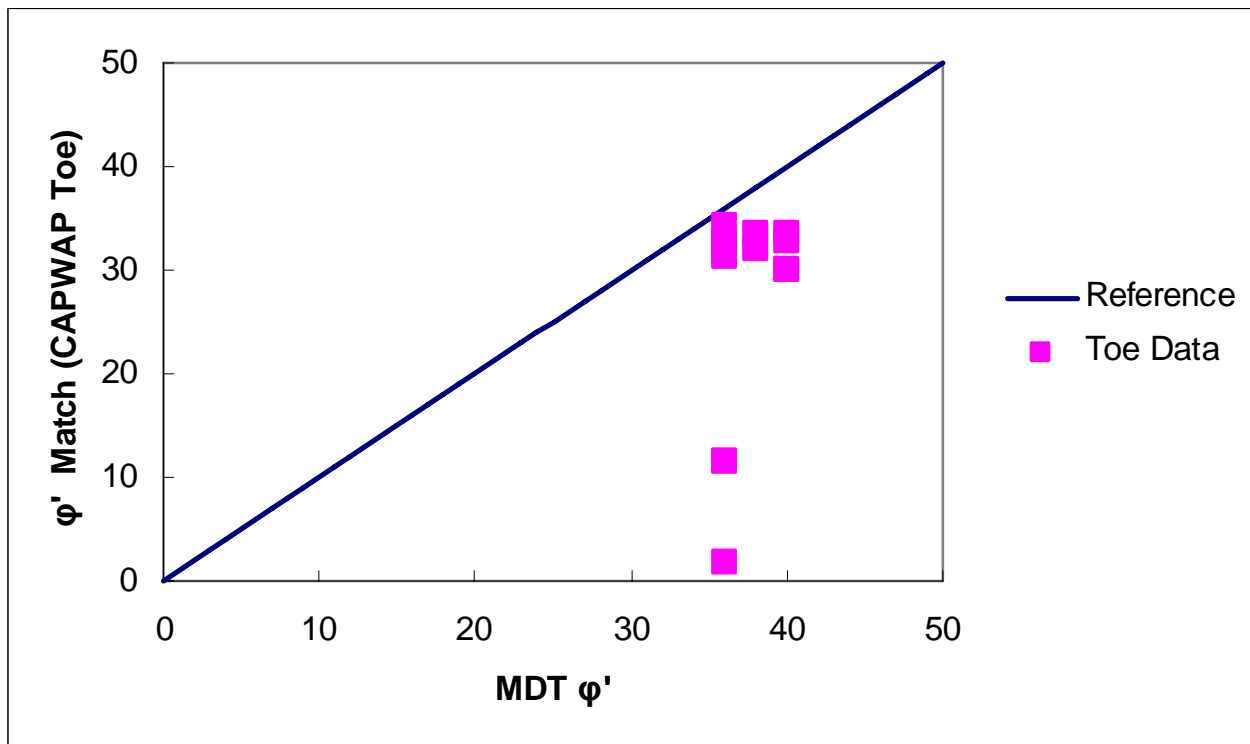


Figure B.2. Cohesionless Toe Capacity Correlation

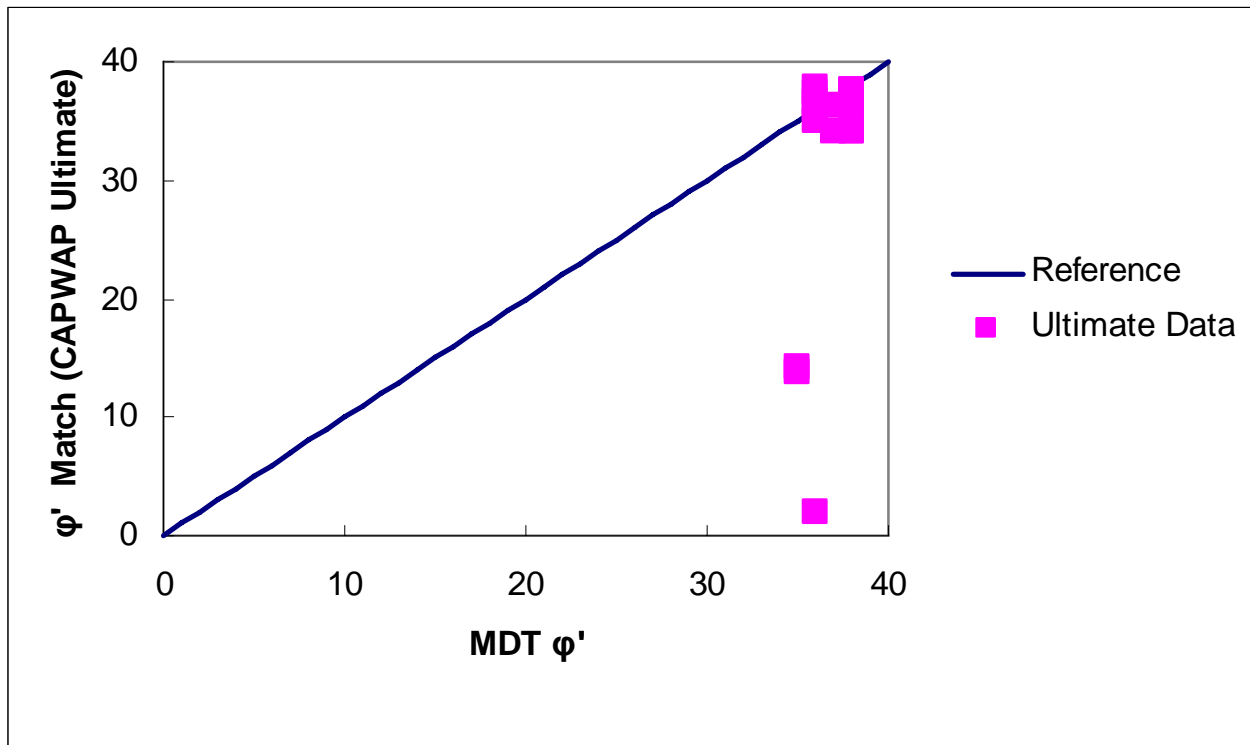


Figure B. 3. Cohesionless Ultimate Capacity Correlation

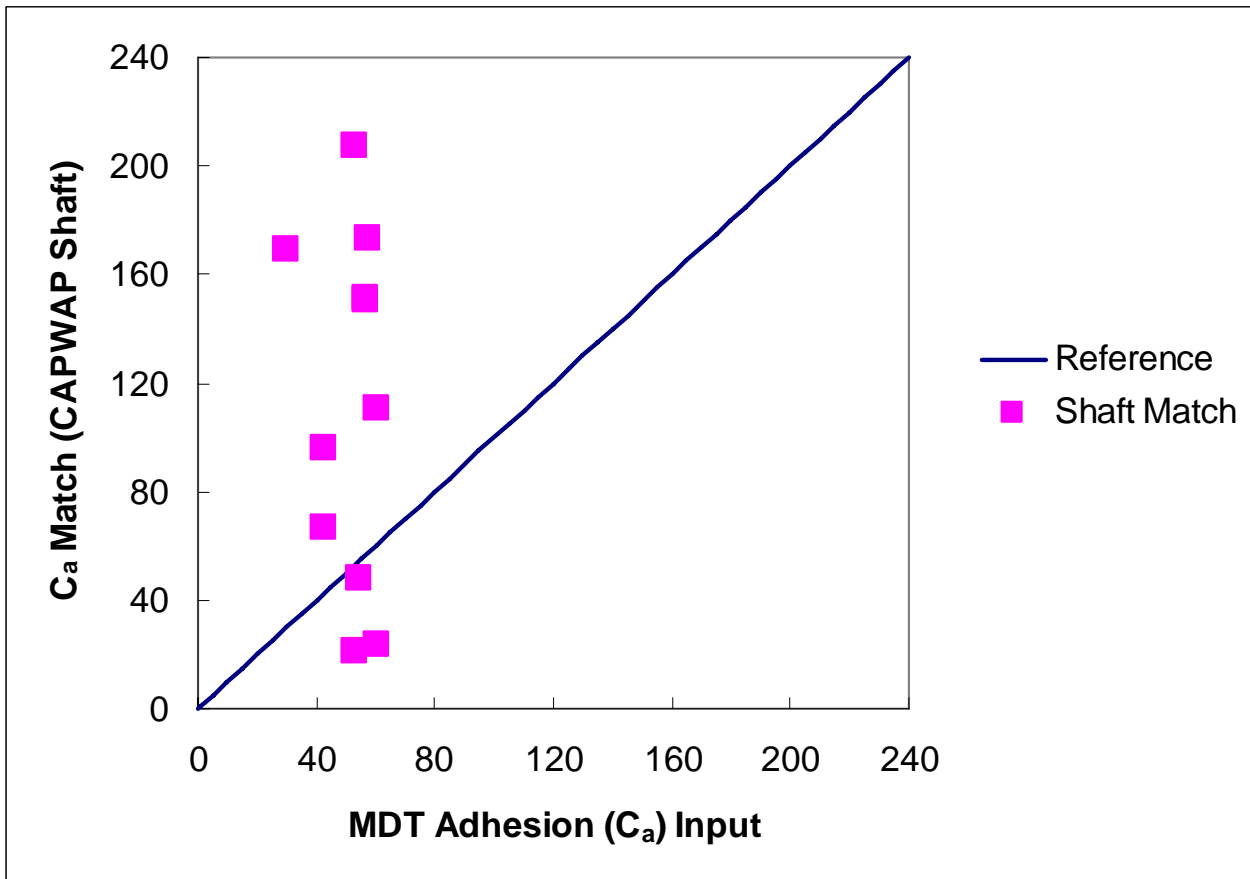


Figure B.4. Adhesion Shaft Capacity Correlation

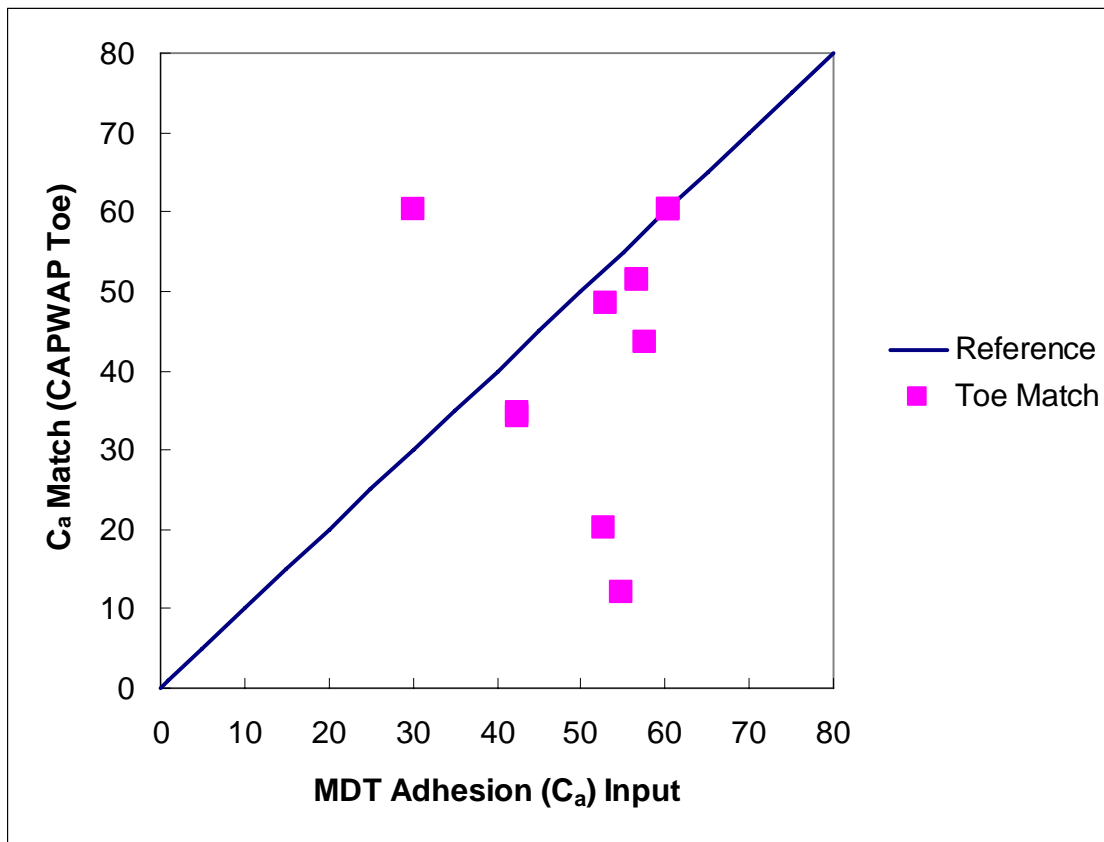


Figure B.5. Adhesion Toe Capacity Correlation

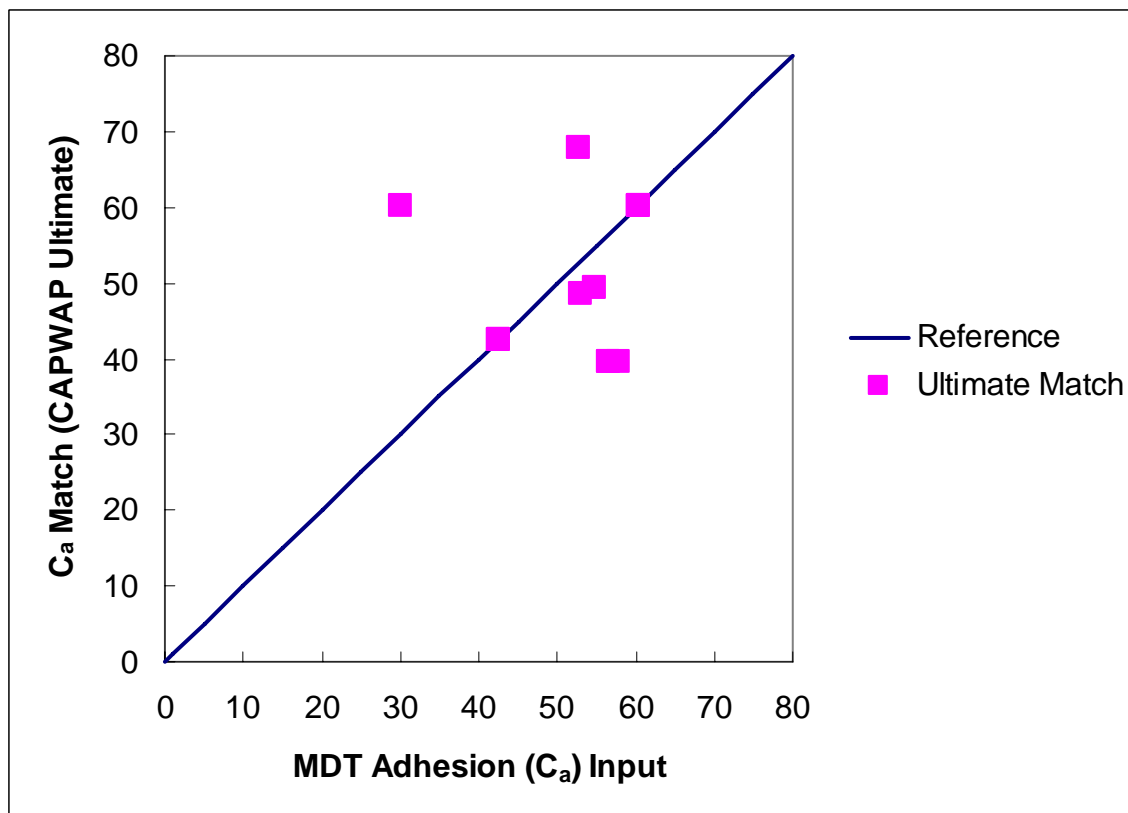


Figure B.6. Adhesion Ultimate Capacity Correlation